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Responding climate change: A bibliometric review on urban environmental governance

Fei Wu [a], Yong Geng [a, b, c, *], Xu Tian [a], Shaozhuo Zhong [a], Wei Wu [d], Shitong Yu [a], Shijiang Xiao [a]

[a] School of Environmental Science and Engineering, Shanghai Jiao Tong University, Minhang, Shanghai, 200240, China
[b] China Institute for Urban Governance, Shanghai Jiao Tong University, No. 800 Dongchuan Road, Minhang, 200240, China
[c] Shanghai Institute of Pollution Control and Ecological Security, Shanghai 200092, PR China
[d] China-UK Low Carbon College, Shanghai Jiao Tong University, Minhang, Shanghai, 200240, China

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ABSTRACT

Urban environmental governance is critical for responding climate change. Existing policies have been inefficient for addressing complicated socio-ecological issues. In order to further promote related studies, it is critical to have a comprehensive review so that recent research progresses can be summarized and future research directions can be identified. Under such a circumstance, this paper aims to conduct a bibliometric review on urban environmental governance, with a focus on addressing climate change. Based on 1697 articles published from 1997 to 2017 and searched from Web of Science, a systematic method combining bibliometric analysis and network analysis is applied to uncover the dynamic trends, academic collaboration and research hotspots. Results show that the overall publication quantity had been gradually improved. The key journals include Journal of Cleaner Production, Sustainability and Energy Policy. Authors from USA have the most publications and international co-authorships, followed by China and UK, while the most influential institution is the Chinese Academy of Science. Moreover, research keywords have been identified, including GHG emission, energy, water, health and transport. In terms of research methods, life cycle assessment and ecological footprint are the dominating methods. In order to further improve research in this field, it is crucial to combine different methods so that more innovative perspectives can be presented. Research findings from this study can also provide valuable policy insights to policy-makers so that appropriate urban environmental governance policies can be raised to mitigate the overall greenhouse gas emission.

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1. Introduction

Due to rapid urbanization and industrialization, cities have become key areas of air and water pollution, resource depletion, energy consumption and greenhouse gas emissions (GHG emissions). According to the Fifth Assessment Report of Intergovernmental Panel on Climate Change (IPCC-AR5), the burdens of urbanization on urban ecosystem services, public health and global warming have been growing in an inevitable way (Field et al., 2014). Moreover, urbanization is prevalent worldwide and the global urbanization rate reached 54% in 2017. Such a rate will increase by 28% in the next 15 years (Population Reference Bureau, 2018; Cohen, 2015). Urban environmental governance refers to the process through which democratically elected local governments and the range of stakeholders in cities – such as business associations, unions, civil society, and citizens – make decisions about how to plan, finance, and manage urban environmental issues together. Effective urban environmental governance can help transit one city toward a low-carbon and eco-efficient city (Lemos and Agrawal, 2006). Consequently, it is of great urgency to initiate appropriate urban environmental policies to deal with these emerging social-ecological issues so that the overall urban sustainability can be improved.

Both international organizations and academic communities have paid great attentions on addressing climate change related issues through urban environmental governance. Several international organizations are actively facilitating and recommending policies instruments to tackle with emerging environmental challenges. In this regard, Organization for Economic Co-operation and

* Corresponding author. School of Environmental Science and Engineering, Shanghai Jiao Tong University, Minhang, Shanghai, 200240, China.
E-mail address: ygeng@sjtu.edu.cn (Y. Geng).

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Nomenclature

EF	Ecological Footprint
EPOC	Environment Policy Committee
GHG	Greenhouse Gas
GIS	Geographic Information System
IPCC	Intergovernmental Panel on Climate Change
LCA	Life Cycle Assessment
OECD	Organization for Economic Co-operation and Development
SD	System Dynamics
STIRPAT	Stochastic Impacts by Regression on Population, Affluence and Technology
WOS	Web of Science

Development (OECD) set up the Environment Policy Committee (EPOC) in 1971, of which the related report has estimated the Value of Statistical Life and provided valuable policy implications on the health impacts of road transport as well as the economic costs (OECD, 2014). Another recent report described the feasible pathways for governments to achieve inclusive economic growth and reach the Paris Climate Agreement objectives of climate change at the same time (OECD, 2017). In addition, cities have become the key focus for global policy makers to address climate change concerns (United Nations, 2015).

Academic progresses have also been made for improving urban environmental governance to combat climate change. Most relevant papers focus on urban CO_2 emissions mitigation, urban energy structure optimization and the construction of smart cities. For instance, the driving factors of embodied carbon emission were uncovered in cities of Liaoning province, China so that mitigation policies for low carbon development can be raised (Geng et al., 2013b). Combining carbon footprint and system dynamics methods, carbon reduction potential from public transportation was assessed, hence building up a solid basis for urban climate policies in the USA (Ercan et al., 2016). Likewise, an innovative waste-to-energy system was recently proposed to increase energy recovery efficiency for cities to transit toward smart cities and various policies and feasible technologies were also discussed (Ohnishi et al., 2018). In addition, Cohen (2015) proposed that it is critical to set up proper information platforms to facilitate cities toward post-fossil carbon societies, including necessary capabilities to combat climate change.

These studies raised several policies to address various environmental concerns because existing policies have been proved to be ineffective and inefficient for systematically responding climate change (Runhaar et al., 2009, 2018). Particularly, with rapid urbanization process, cities become larger and larger and are facing more complicated social-economic challenges, leading to a need of more innovative urban environmental governance (Hughes et al., 2017). Although many published papers cover different perspectives of urban environmental governance, it is critical to have a comprehensive literature review so that scholars in this field can understand current research progress and identify possible research directions for their future work.

Under such a circumstance, this paper aims to fill this research gap by summarizing recent progresses and research hotspots. Different from conventional literature review, the bibliometric method provides an innovative and objective perspective through reproducible, quantitative and reliable processes (Persson et al., 2004). Successfully employed in several reviews, the bibliometric analysis has been proved to be helpful in reviewing natural resource accounting, supply chain management, energy consumption, etc (Feng et al., 2017; Geng et al., 2017; Zhong et al., 2016). In order to further identify the cooperation between different authors, institutions, regions and key words, network analysis method was integrated with bibliometric analysis method in this review to reveal the dynamic trends and academic features of related publications from 1997 to 2017.

The rest of this paper is organized as follows: after this introduction section, Section 2 elaborates research methods and data sources. Section 3 presents the main research findings, including the general trends of related publications and citations, major research areas and journals, as well as academic performance of different countries/regions, organizations and authors. Section 4 discusses policy implications and Section 5 draws research conclusions.

2. Methods and data

2.1. Methods

A hybrid method combining both bibliometric analysis and network analysis was adopted in this study (Fig. 1). Bibliometric analysis is a systematic method that can quantitively uncover the publication trend and research hotspots of emerging topics, and assess academic performance from different perspectives (Persson et al., 2004). As a widely applied bibliometric toolbox, BibExcel can facilitate users in processing academic bibliographic data from Web of Science, Scopus, ScienceDirect and other mainstream databases (Persson et al., 2009; Tian et al., 2018a). Basic information (e.g. authors, citations and keywords) of published papers can be extracted by the utilization of various tools in BibExcel. Further visualization and in-depth network analysis can be accomplished through the integration with Excel, Pajek and Gephi (Fahimnia et al., 2015).

Network analysis provides valuable insights into complicated social relationship among different actors, which comprise authors, institutions, regions and keywords (Scott, 2017; Wasserman and Faust, 1994). The application of network analysis can help identify the authors' collaboration, institutions' co-citation and research hotspots from the topologized network. In this study, the *.net files from BibExcel were imported into Gephi software for network analysis. Gephi is an ideal software for bibliometric review due to its processing capacity on big data and high-resolution figures (Bastian et al., 2009). Moreover, cluster analysis and *h*-index were also applied by utilizing tools from Gephi. Widely integrated in network analysis, cluster analysis offers the mathematic basis for identifying collaborative groups and features of productive scholars (Everitt et al., 2011). The *h*-index is a frequently-used indicator to assess both the quantity and quality of one author' academic publications. It is defined as the total papers published by one scholar which have been cited at least *h* times (Bornmann and Daniel, 2007).

2.2. Data sources and treatment

Web of Science is one of the most influential databases that offer standardized and high-quality academic publication information. Therefore, it was selected to provide original data in this study. The retrieval data include publication titles, abstracts, authors, keywords and institutions. To ensure data accuracy, a three-level keywords refinement was applied. Fig. 1 shows this review flowchart.

Level 1 filters data containing environmental governance or policy related keywords. Publications related with climate change were then searched at level 2, which represents the key context of

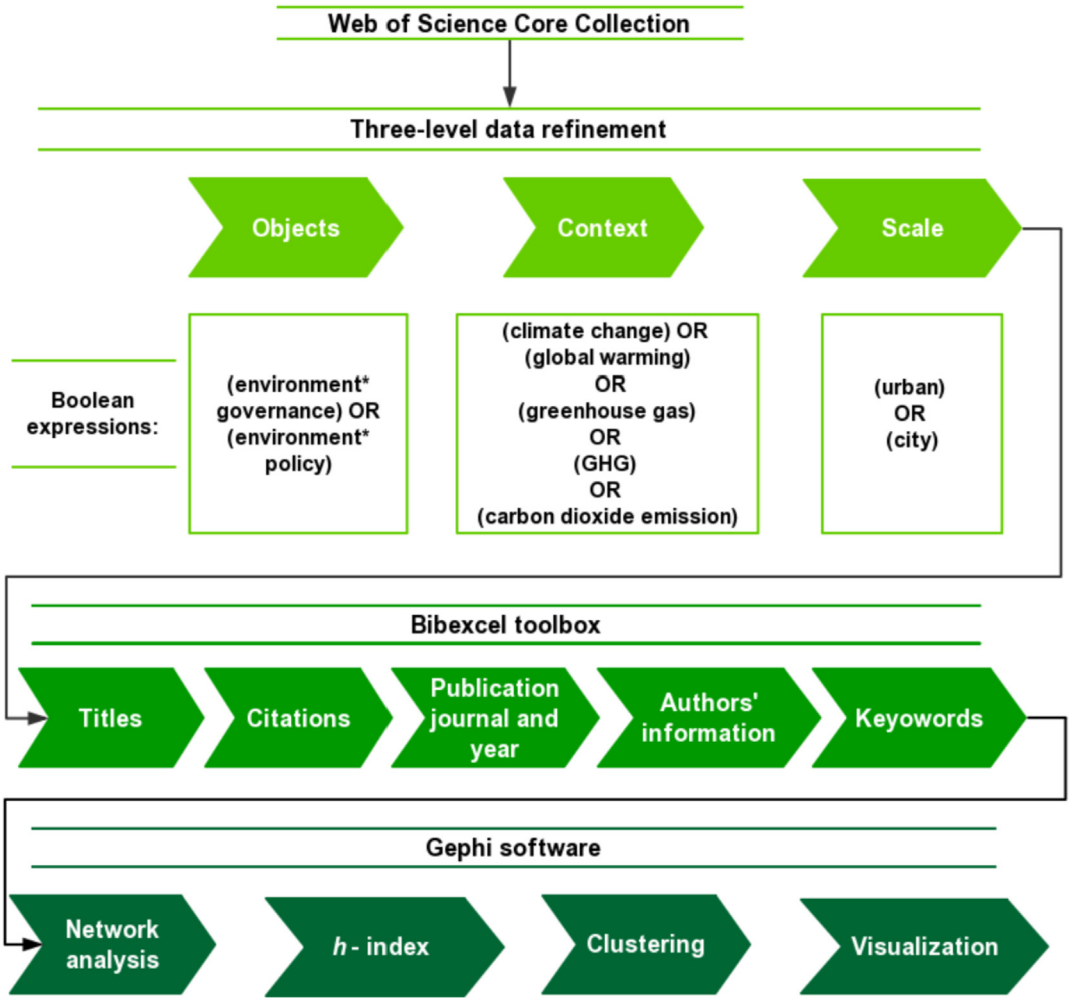

Fig. 1. A flowchart of systematic bibliometric review (note: * is a truncation symbol enabling different forms of a word to be searched simultaneously).

this review. To clarify the research scales, urban related keywords were then added at level 3. The final dataset was set up after three levels screening. Since English language publications are globally accepted, only those publications in English are reserved for further analysis. Plus, the study period is set from year 1997–2017 so that the most recent research progress can be uncovered. Initially, 2055 results were collected. Among all these searched publications, research articles and review articles are the majority publications (88%). Since other types of publications (such as book chapters, editorials, comments and short communications) are relatively less, they were excluded from our analysis. Finally, both manual screening and BibExcel software were applied to remove irrelevant publications, resulting in that 1697 publications were reserved for bibliometric analysis. Irrelevant publications refer to those papers without any substantial contribution to urban environmental governance. For instance, Call-for-Paper articles were removed since such papers do not have clear academic contribution to the knowledge of this field.

3. Results

3.1. General trends of publications and citations

The annual numbers of publications (NP) and average citations per year (ACP) were presented in Fig. 2. It is clear that both NP and ACP increased dramatically, indicating the growing academic interest in urban environmental governance in the context of climate change. During 1997–2005, both NP and ACP were too few due to the lack of concerns on climate change and urban environmental issue. However, both NP and ACP had gradually increased from 2006 to 2009, and then rapidly increased since 2010. The NP published in 2017 almost quintupled the figure of year 2010. Likewise, the ACP in 2017 was over nine times higher than the one in 2010. The main reason is that international societies have paid more attentions on such a topic in the last decade, particularly, the Paris Climate Agreement was achieved in 2015, leading to more research attentions in this field.

3.2. Major disciplines and journals

According to Web of Science (WOS), the related publications can be categorized into seven major academic disciplines (according to the default discipline classifications of WOSs). As shown in Fig. 3, the majority of published papers belong to environmental sciences and environmental studies, accounting for 23% and 18% of the total publications, respectively. In terms of other disciplines, the proportion of green sustainable science is 10%, followed by energy fuels (6%), environmental engineering (6%), urban studies (6%), economics (5%) and others (26%). In general, most papers belong to environmental fields, while less papers belong to social science

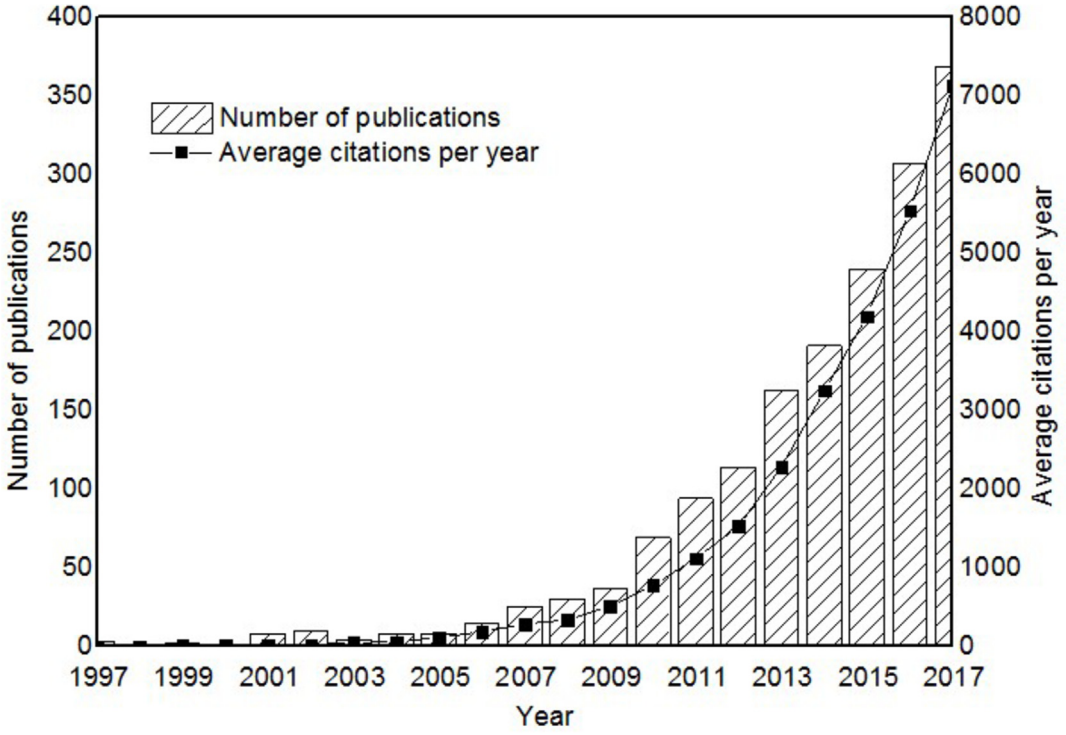

Fig. 2. General trends of selected publications from 1997 to 2017.

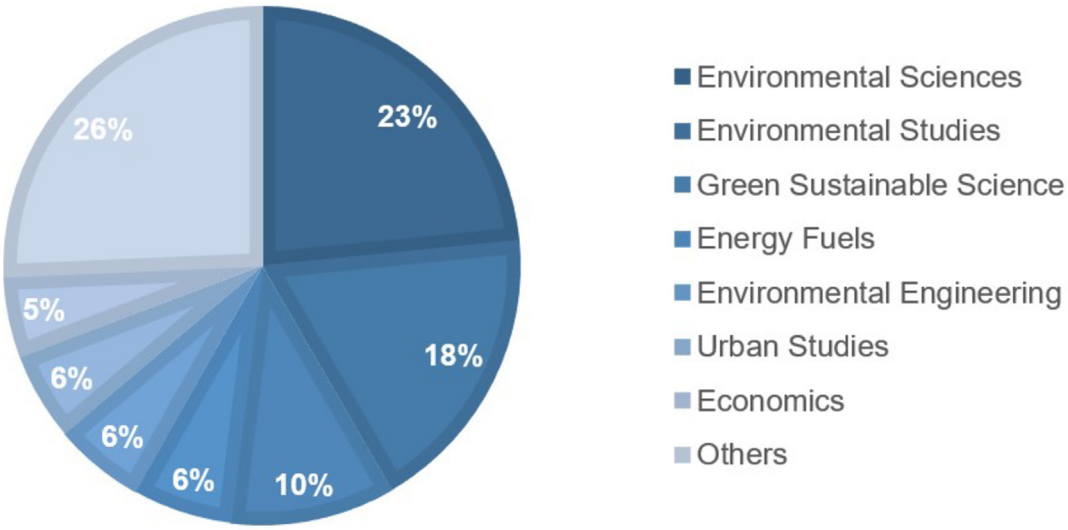

Fig. 3. Major disciplines and their proportions.

fields.

Similarly, the most productive journals are also closely related to environmental and ecological disciplines. These 1697 selected papers were published in 535 different journals. Table 1 lists the top 10 most productive journals, including the detailed publications in different journals, as well as the percentages and impact factors. Journal of Cleaner Production is the most productive journal with over 4% of the total publications. The second most productive journal is Sustainability (3.48%), followed by Energy Policy (3.06%) and Environmental Science & Policy (2.18%). Most top 10 productive journals belong to Elsevier, one of the most famous academic publishing companies in the world.

3.3. Academic performances of different stakeholders

The academic performance of different stakeholders was categorized into three levels: countries/regions (macro level), organizations (meso level) and authors (micro level). Such categorization can provide a better understanding on major authors, mainstream institutions, countries/regions, and their collaborative network. The performance results can help new researchers in this field quickly identify the potential collaboration partners and institutions.

3.3.1. Macro level: countries/regions

In total, authors from 92 countries/regions published their

Table 1
Top 10 productive journals in this field from 1997 to 2017.

Journal name	Publications (Rank)	Percentage	Impact factor (2017)
Journal of Cleaner Production	75 (1)	4.42%	5.715
Sustainability	59 (2)	3.48%	1.789
Energy Policy	52 (3)	3.06%	4.140
Environmental Science & Policy	37 (4)	2.18%	6.198
Renewable & Sustainable Energy Reviews	34 (5)	2.00%	8.050
Current Opinion in Environmental Sustainability	21 (6)	1.24%	3.954
Habitat International	19 (7)	1.12%	2.285
Science of the Total Environment	18 (8)	1.06%	4.900
Atmospheric Environment	18 (8)	1.06%	3.629
Ecological Indicators	18 (8)	1.06%	3.898

papers on urban environmental governance with foci on addressing climate change. Table 2 lists the top 20 most productive countries. The USA is the most productive country with over 470 publications, accounting for 18.8% of the total publications, followed by China (12.0%) and UK (10.6%). Other productive countries/regions include several European and Asian countries, Brazil and South Africa, indicating a global concern on this research topic. China is the only developing country among the top 10 productive countries, reflecting China's increasing academic attentions on this field. This is not surprising since China is the largest greenhouse gas emitter in the world and is experiencing fast urbanization (Geng et al., 2013b).

As an effective method to reveal the collaborative features among different countries/regions, network analysis was then applied and visualized in Fig. 4. Using Gephi as a toolbox for network analysis, major countries with international collaboration over 30 times were identified and plotted. The size of each node represents the total international collaborative publications of one country/region. This means that a country/region with a lager node is more internationally active in the field of urban environmental governance to address climate change. Similarly, the width of one connecting line reflects cooperative frequency. For instance, academic collaboration between USA and China is far more frequent than that between China and Germany. Generally speaking, USA is the most influential nation having close international cooperation with UK, Canada, Australia and China. In addition, more cooperation activities were found among European countries and North American countries due to their cultural and language linkages. With regard to Asian nations, fewer academic connections were found. Possible reasons may include language, culture and finance barriers (Tian et al., 2018a; Zhong et al., 2016).

3.3.2. Meso level: organizations

Table 3 lists the performance of the top 10 active academic organizations, including their belonged countries, total publications, average citations per publication. Chinese Academy of Science was the most productive institution with 56 publications, followed by Arizona State University (37 publications). However, the average citations per publication of Arizona State University are more than double the Chinese Academy of Science. Likewise, all four Chinese organizations had relatively less average citations per publication. Even the Australian National University (ranked #10) had higher average citations per publication than the Chinese Academy of Science (ranked #1), indicating the lack of academic influence and popularity of these Chinese organizations. Under such a circumstance, it is urgent for the Chinese institutions to improve their academic quality. The rest of more productive organizations are mainly from the top 4 productive countries (See Table 2). Particularly, except China, the USA, UK and Australia are all industrialized countries and have paid adequate attentions on urban climate change issues. In addition, the high urbanization rates in these countries have further contributed to their academic progress in this field (Ercan et al., 2016).

Table 2
Top 20 active countries/regions from 1997 to 2017.

#	Country	Publications (%)	#	Country	Publications (%)
1	USA	471 (18.8%)	11	Japan	63 (2.5%)
2	China	302 (12.0%)	12	France	50 (2.0%)
3	UK	267 (10.6%)	13	Brazil	43 (1.7%)
4	Australia	176 (7.0%)	14	India	38 (1.5%)
5	Canada	107 (4.3%)	15	Malaysia	37 (1.5%)
6	Netherlands	93 (3.7%)	16	Switzerland	35 (1.4%)
7	Italy	78 (3.1%)	17	South Africa	34 (1.4%)
8	Germany	74 (2.9%)	18	South Korea	29 (1.2%)
9	Sweden	68 (2.7%)	19	Singapore	28 (1.1%)
10	Spain	64 (2.6%)	20	Denmark	27 (1.1%)

3.3.3. Micro level: authors

Table 4 lists the top 7 most productive authors in this research field. Ranked by their productivity, all the listed scholars had at least 9 publications in this field. To further evaluate their academic performances, both *h*-index and average citations per publication were adopted. It is clear that different authors have different citation records. Both Drs. Liu Z and Geng Y have more citations per publication, while Drs. Huang GH and Li J have less than ten citations per publication. But their *h*-indexes are very similar, ranging from 5 to 7.

Additionally, manual review was further conducted to clarify the specific research areas of these authors. Most of them focused on GHG emissions at the city level, although from different perspectives. For instance, De Oliveira (Getulio Vargas Foundation, Brazil) mainly investigated urban climate policies, while Li J (École des Ponts ParisTech, Marne-la-Vallee, France) paid more attention on urban climate economics. Urban emissions accounting is another key research area, represented by Liu Z (University of East Anglia, UK) whose average citations and *h*-index were both the highest. Also, as the key research areas of circular economy, urban and industrial symbiosis was investigated mainly by Geng Y (Shanghai Jiao Tong University, China).

The clustering of major scholars' network (authors with over 7 publications) was plotted by utilizing Gephi and shown in Fig. 5. Three main academic groups can be identified in Fig. 5. The largest research cluster is centered on Zhang Y, whose research foci include urban energy and GHG emission. Close connections were also identified between Cluster 1 and Cluster 2. Geng Y, Liu Z, Fujita T and Dong L formed the second academic cluster, whose research fields include urban and industrial symbiosis, urban GHG emission accounting and urban climate mitigation. Cluster 3 includes De Oliveira, Doll C and Balaban O, with a research foci on urban GHG emission mitigation and urban climate change policies.

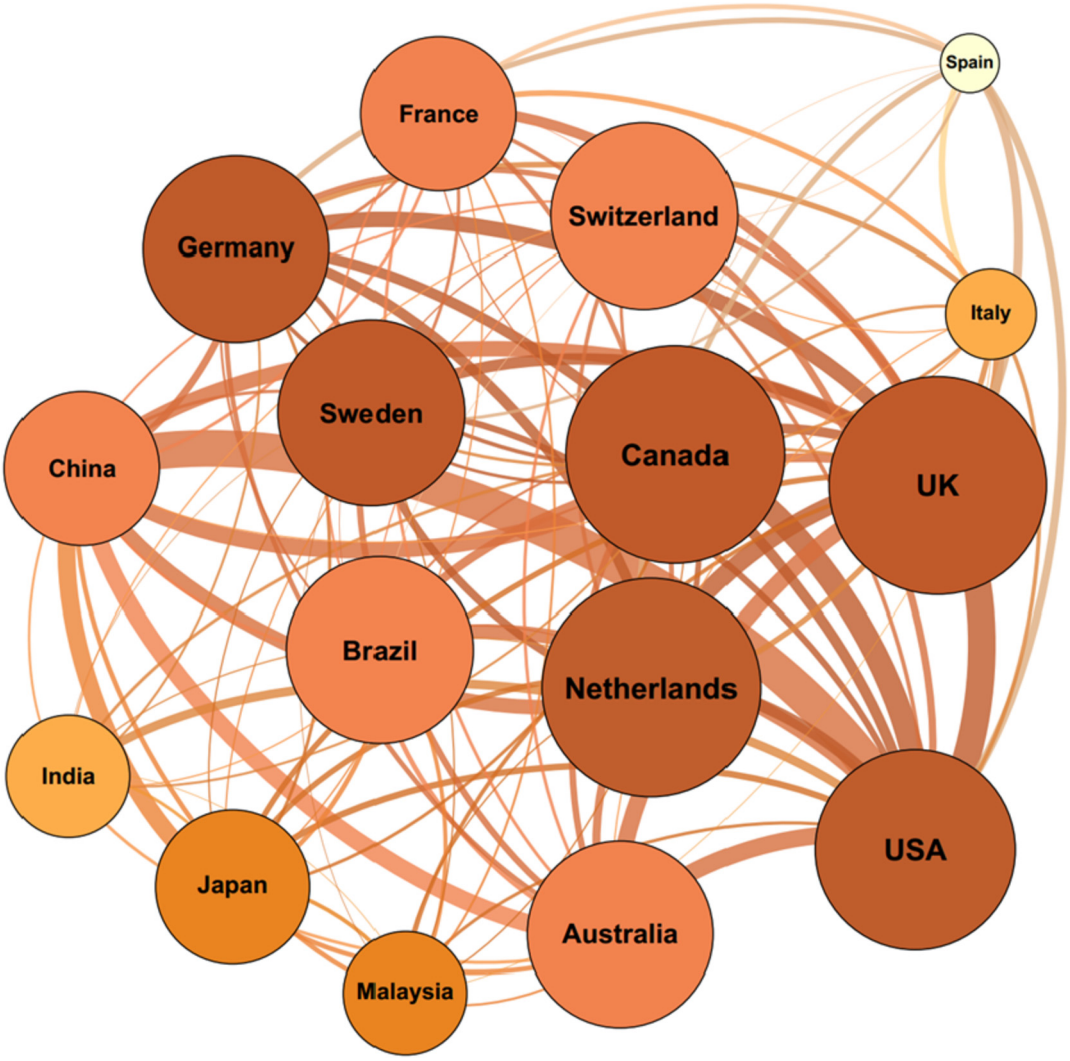

Fig. 4. Academic cooperation among major countries/regions.

Table 3
Top 10 productive organizations from 1997 to 2017.

Organizations	Publications (%)	Country	Average citations per publication
Chinese Academy of Science	56 (3.3%)	China	15.0
Arizona State University	37 (2.2%)	USA	32.5
Beijing Normal University	29 (1.7%)	China	13.0
University College London	29 (1.7%)	UK	26.5
UC Berkeley	27 (1.6%)	USA	17.1
University of Leeds	26 (1.5%)	UK	30.9
Peking University	23 (1.4%)	China	16.0
Tsinghua University	23 (1.4%)	China	16.1
University of Oxford	23 (1.4%)	UK	23.2
Australian National University	20 (1.2%)	Australia	17.5

3.4. Classification of keywords

Keywords represent the research foci of academic articles, such as research objects, methodologies, study areas, purposes, etc. Therefore, the classification of keywords can to help identify leading and emerging topics in the research field. A total of 4312 keywords were extracted from 1697 publications by using Bibexcel. To ensure the reliability of the selected keywords, manual refinement was conducted to merge the keywords with similar meanings. For instance, “global warming” and “climate change” implicate the similar content and were integrated into one keyword “climate change”. To provide a clear visualization, the keywords appeared over 3 times were classified and plotted in Fig. 6. As illustrated in the pie chart, the major keywords can be logically categorized into four broad classifications, namely, the purposes, the objects, the study regions, and the methods.

Table 4
Comparison and clustering of the top 7 productive authors.

Authors	Publications (Average[a])	*h*-index	Cluster	Research area[b]
Zhang Y	11 (13.3)	6	1	Energy and carbon emission
Dong L	10 (12.9)	6	2	Low-carbon city and industrial symbiosis
De Oliveira Jap	9 (18.7)	5	3	Climate change mitigation and policy
Geng Y	9 (23.3)	7	2	Urban and industrial symbiosis and carbon emission
Huang GH	9 (9.9)	6	1	Stochastic energy system and GHG emission management
Li J	9 (8.6)	5	1	Economics and policies for mitigating GHG emission
Liu Z	9 (33.2)	7	2	Carbon emission accounting and mitigation

[a] Average stands for average citations per publication.
[b] Research area was summarized from the selected publications in the dataset established by this paper.

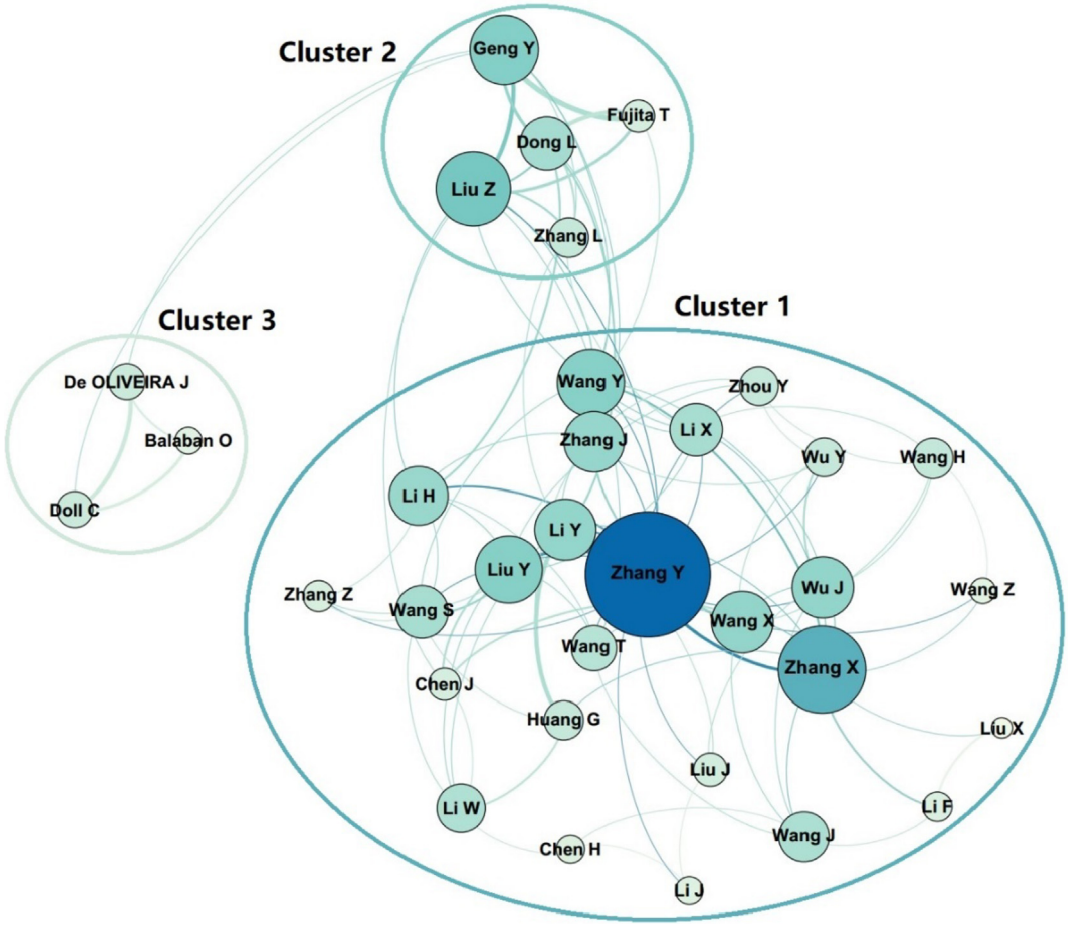

Fig. 5. Academic collaboration among major authors.

3.4.1. Research purposes

Over half of the identified keywords are related with research purposes. By classifying these keywords into sub-categories, the research purposes can be further categorized into policy, management, environment, planning, etc. Policy is the No.1 research purpose in the selected publications, of which the related keywords include urbanization policy (27.95%), general policy (22.62%), environmental policy (21.04%), justice policy (5.62%), and economic policy (5.48%), etc. As an energy-consuming and pollution-intensive process, urbanization has attracted a great attention from both scientists and policy makers. In order to facilitate urbanization in an environmental-friendly way, many published papers focus on polices related with urban plan, urban transport, urban metabolism, urban green space, urban density and urban land-cover change. As for the keyword of management, almost half of the keywords are related with climate change mitigation and adaptation, followed by sustainability with a rate of 19.97%. That is to say, carbon emission mitigation and adaptation is another key goal for urban environmental governance. Besides, risk management (with a rate of 5.95%) is also one of the important research purposes since all the cities are facing various risks, not only natural risks (such as typhoon, rainstorm, snowstorm, earthquake), but also artificial ones (such as terrorism, chemical releases, fires, explosions, etc). Any of these will result in a large amount of economic loss and social chaos, leading to a critical need of appropriate policies. Other policies relate with urban community, stakeholders and responsibility management, referring to the study of social science. Moreover, the purposes of environment and planning are the third

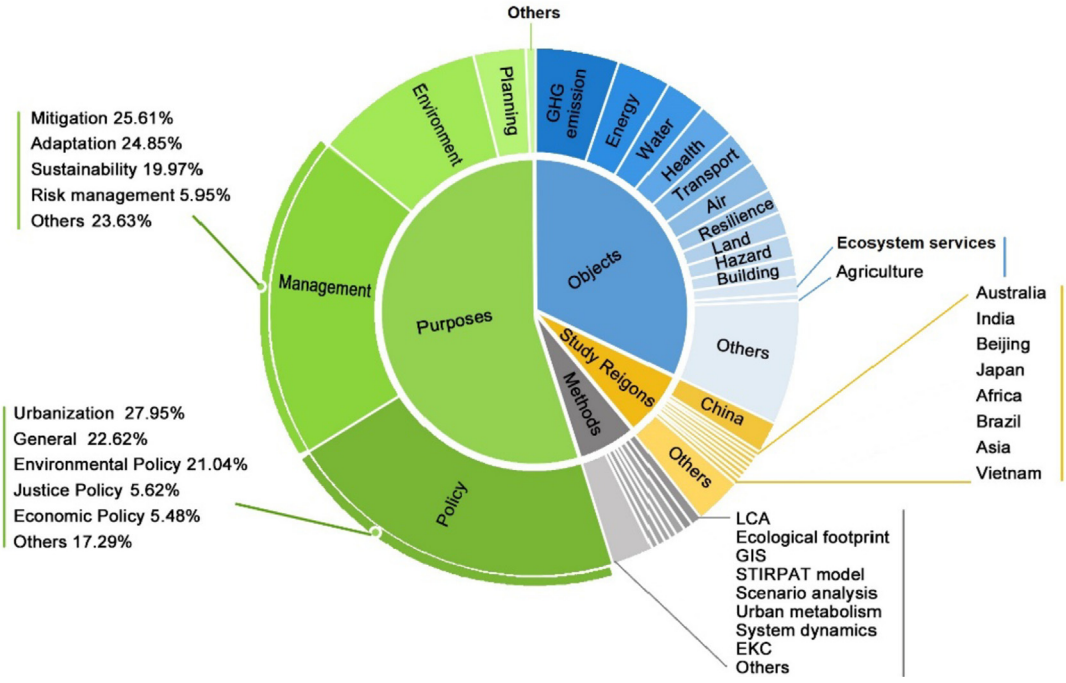

Fig. 6. Classification of main keywords.

and fourth largest ones (with rates of 9% and 6%, respectively). This indicates that there is a strong need on improving urban environmental quality through scientific planning efforts. Relevant keywords include environmental impact, urban design, spatial planning, collaborative planning and environmental planning.

3.4.2. Research objects

Research object is the second largest portion of the keywords classification. Major research objects include GHG emission, energy, water, health, transport, air, resilience, land, hazard, building, ecosystem services and agriculture. Shown in Fig. 6, research objects are relatively diversified. In general, most research objects belong to the disciplines of Environment, Energy and Ecology. For instance, as the mainstream research objects of environmental science, GHG emission, water and air account for 16%, 8% and 6% of the total keywords, respectively. Closely related to GHG emission, energy ranks second among all the sub-categories of research objects. Transport is another key sector having a great influence on urban climate change, thus having received considerable academic attention (Tian et al., 2018b). Similarly, buildings consume a large amount of energy and generate corresponding GHG emission, thus receiving a lot of concerns. In addition, academic attention has also been paid on the objects related to the adaptation in this research field, including health, resilience, hazard and ecosystem services. In order to better adapt to climate change at the city level, these research objects will receive more academic attentions.

3.4.3. Research regions and methods

Although research regions and methods only account for 7.5% and 5.8% of the total keywords, they deserve to be further investigated so that research geographical disparity and mainstream methods can be recognized. In terms of research regions, most studies are about developing countries, among which China is the most investigated country. This is not surprised since China is the largest GHG emitter in the world and its rapid urbanization contributed to the huge amount of GHG emissions (Barboza, 2010). Also, the Chinese government has paid great attentions on addressing climate change, such as releasing the nationally determined contributions and national carbon emission intensity reduction targets (Geng, 2011). Under such a circumstance, many mitigation efforts have been initiated (Geng et al., 2017), such as low carbon demonstration cities and industrial parks, leading to many case studies related with this topic. For instance, as the capital of China, Beijing is one hot spot city among all the investigated regions and is actively seeking effective mitigation policies (Creutzig and He, 2009). Other most investigated developing countries include India, several African countries, Brazil and Vietnam. The only two developed countries listed in the major study regions are Australia and Japan.

With regard to research methods, various methods have been applied since this topic is very comprehensive and therefore cannot be solved by one single method. A key feature is that all these methods are interdisciplinary since they cover different subjects ranging from ecology to economics. Life cycle assessment (LCA), ecological footprint (EF) and geographic information system (GIS) are the dominating methods, accounting for about 30% of all the applied methods. Other key methods include Stochastic Impacts by Regression on Population, Affluence and Technology model (STIRPAT model), scenario analysis, urban metabolism, system dynamics and environmental Kuznets curve (EKC).

4. Discussions

4.1. Mainstream methods

Due to the complexity of responding climate change at the city level, any single method cannot address the related social, economic and ecological issues at the same time. Consequently, it is critical to integrate different methods so that innovative perspectives can be presented. Table 5 lists six mainstream methods in this research field, including life cycle assessment (LCA), ecological footprint (EF), geographic information system (GIS), STIRPAT model, scenario analysis and urban metabolism. These methods can be classified as ecological methods (such as LCA, EF, urban

Table 5
Comparison of major methods.

Methods	Initiator (Year)	Definition	Advantages	Deficiencies
EF	Wackernagel and Rees (1992)	The biologically productive land and water required for supporting a population. (Dong et al., 2016)	A valuable tool to analyze sustainable development and budget-limited natural capital and can be easily understood by policy makers. (Dong et al., 2016; Wackernagel et al., 2006)	The equivalence factors and yield factors are difficult to obtain. (Dong et al., 2016)
LCA	Coca-Cola Co. (1960)	"*Compilation and evaluation of the inputs, outputs and the potential environmental impacts of a product system throughout its life cycle.*" (ISO, 2006)	A reliable tool for environmental management and decision-making, with detailed accurate and precise counting processes. (Dong et al., 2016; Filimonau, 2016)	Data collection is complicated and time-consuming, while the delineation of system boundary may cause systematic truncation error. (Dong et al., 2016; Suh et al., 2004)
GIS	Canadian government (1960s)	"*A computer application designed to perform a wide range of operations on geographic information.*" (Goodchild, 2009)	It is useful for combining real-time accurate geographical data to assess the potential impact of global warming. (Heikkinen et al., 2006; Keleher and Rahel, 1996)	Geo-data of high-resolution are incomplete or even classified, especially in developing countries. "*It has no procedures exist to avoid violating of a single property conceptualized as a continuous field.*" (Goodchild, 2009)
STIRPAT Model	Rosa and Dietz (1990s)	The model analyzing stochastic impacts by regression on population, affluence and technology. (Fan et al., 2006)	It has universality for all environmental impacts and can calculate the total CO2 emissions among inter-disciplinary actors. (Fan et al., 2006; Lin et al., 2008; Rosa and Dietz, 1998; York et al., 2003)	It has no representation of prices or measures of equality. (Liddle and Lung, 2010)
Scenario Analysis	/(1970s)	"*Conjectures about what might happen in the future*"(Cornish, 2004) that identify the consequences and the most appropriate responses under different scenarios. (Duinker and Greig, 2007)	For sustainable development, it is a useful method in organizational planning and participatory exercises. It is a great method to support strategic decision makers. (Duinker and Greig, 2007; Postma and Liebl, 2005)	It has limitations in lack of diversity and had trouble in dealing with simultaneous trends and countertrends. (Postma and Liebl, 2005; Schoemaker, 1998)
Urban Metabolism	Wolman (1965)	"*The sum total of the technical and socio-economic processes occurring in cities, resulting in growth, production of energy and elimination of waste.*" (Kennedy et al., 2007)	It provides a synthetic metabolism of urban population, economics, and environment. It is a leading method to quantify energy consumption and its patterns for urban environmental policies. (Moore, 2007; Pincetl et al., 2012)	It is short of comprehensive assessment of the entire processes of urban energy systems. It fails to explain regional disparity and the reasons for urban metabolism changes. (Barles, 2009; Pincetl et al., 2012)

metabolism and GIS) and economic methods (such as STIRPAT model and scenario analysis).

LCA is the most utilized method and is ideal for assessing the impact of a product or service or even one region through its entire life cycle. Such a rigorous assessment is able to measure the downstream environmental impact, which can build up a solid foundation for environmentally friendly policies. For instance, LCA has been utilized to analyze the GHG emission reduction of the application of ground source heat pump in the Chinese city of Shenyang (Geng et al., 2013a). However, the accurate results of LCA depend on the large amount of high-quality data. Moreover, since LCA is originally developed for a specific product, it fails to assess the indirect flows outside the urban boundaries when applying at the city level (Dong et al., 2016). Similarly, other methods also have their own strengths and weaknesses as presented in Table 5. That is to say, the application of one single method cannot solve the comprehensive issues at the city level.

Under such a circumstance, hybrid methods are more appropriate so that advantages from different methods can be integrated. For instance, an early attempt tried to combine EF with scenarios analysis and system dynamics to create a policy framework for evaluating urban sustainability (Jin et al., 2009). Later in 2016, a system dynamics approach was integrated with LCA to enrich the life cycle framework in the case of urban electric transportation (Onat et al., 2016). Combined with carbon footprint, the reduction potential of urban public transportation sector in the United States was simulated through system dynamics (Ercan et al., 2016). Although system dynamics (SD) is not one of the major methods in this field, it has been frequently integrated with mainstream ecological approaches for policy implications. Particularly, it is effective for simulating different scenarios at the city level or more complicated systems (Forrester, 1961, 1987). Compared with scenario analysis, SD is ideal for addressing more dynamic problems from economic, environmental and social aspects (Sahin et al., 2014). Therefore, the strength of SD could make up for the deficiencies of ecological methods, such as EF and LCA. In general, more innovative and proper combination of different methods are urgently required so that the complexity of urban environmental governance can be addressed.

4.2. Research hotspots and future directions

From the analysis of keywords, research hotspots have been identified, including GHG emission, energy, water, health and transport. As the most notable hotspot, GHG emission has been studied through international collaboration to clarify the major industrial and social sectors for carbon emission reduction and prepare urban low-carbon policies (Xi et al., 2011). Particularly, due to the fact that GHG emission is mainly generated from fossil fuels combustion (such as vehicles, boilers), this topic always relates with air pollution, public health concerns, and energy structure, etc. Therefore, many studies began to address these hotpots together.

For instance, long-range passenger transport and long-term emission changes have been combined together to assess their impacts on public health (Ren et al., 2016). Likewise, human health risk induced by the detrimental urban air pollutants (i.e. PAH_s and variations in PM_{10}-$PM_{2.5}$) was evaluated (Sosa et al., 2017). Policy makers need to consider addressing these issue together so that they can balance among social, ecological and economical perspectives. This is further confirmed by the Second Assessment Report of the Urban Climate Change Research Network that emphasizes several cross-cutting themes at the city level (Rosenzweig et al., 2018).

Another feature of research hotspots is that many case studies were implemented in developing countries, such as China, India and African countries (Fig. 6). However, the most academic productive countries/regions are mainly from developed nations, as presented in Table 2. This finding indicates that urban environmental governance for addressing climate change in developing countries attracted more attentions than from developed countries. The main reason is that the research capacities on such an issue in developing countries are still weak and the climate change impacts on these countries are increasing. Different from other environmental issues, such as air and water pollution, solid wastes, soil contamination, which are mostly regional or local issues, climate change is more global and deserves more international cooperation efforts so that advanced expertise and experiences can be shared and transferred to developing countries. For instance, a great progress has been made in Suzhou Sino-Singapore industrial park by joint efforts of Singapore and China, leading this city toward an eco-city (Yu et al., 2015). In addition, megacities are the ideal places for implementing multi-targeted policies since they are facing more challenges and need more integrated considerations.

4.3. Policy recommendations

Finally, our literature review indicates that it is critical to further propose more innovative mitigation policies. Many published studies recommended useful policy implications by considering the local realities. Due to different economic development levels, energy and resource endowments, industrial structure, culture, and sizes, it is impossible for all the cities to adopt the same mitigation pathway. Each city has to prepare its own mitigation policies by first accounting its own GHG emission trajectories so that key emission sectors and areas can be identified. Then, the city managers and other stakeholders should promote energy efficiency in all the key sectors so that GHG emissions from fossil fuels can be mitigated, such as energy efficient equipment and technologies. During this process, capacity-building activities should be initiated so that the stakeholders can learn the relevant skills and knowledge, such as TV and Internet promotion, workshops, pamphlets and billboards. Also, energy structure optimization should be supported so that the application of renewable and clean energy can be widely applied, such as wind power, solar power, biomass, and geothermal power. City governments should release appropriate policies to support the application of such energy sources, such as financial subsides, carbon trade and tax. These policies can provide more economic incentives so that renewable and clean energy is more competitive in the market. In addition, international and regional cooperation is crucial. International cooperation can help transfer the advanced technologies and policies from developed countries to developing countries, while regional cooperation can help cities with geographical proximity to work together for addressing climate change since one single city cannot solve all the problems by itself due to economic and technological barriers (Liu et al., 2018).

5. Conclusions

Effective urban environmental governance is critical for addressing climate change. However, the existing policies have been proved to be inefficient to deal with such complicated socio-ecological issues. In order to summarize research progresses and identify more appropriate research directions, this paper conducts a bibliometric review by using the data from Web of Science Core Collection for the period of 1997–2017. It is clear that the related publications have gradually increased due to increasing concerns on climate change. The most productive journals in this field include Journal of Cleaner Production, Sustainability and Energy Policy. Authors from USA had the most publications and international co-authorships, followed by China and UK. However, academic connections were still comparatively insufficient in Asian nations due to language and culture barriers. Chinese Academy of Science is the most productive research institution, followed by Arizona State University. By comparing total publications, average citations per paper and *h*-index, the top 7 productive authors have also been identified, including six Chinese authors and one Brazilian author. This reflects that the Chinese authors have actively engaged in this research field. The keywords analysis indicates that policies of urbanization, environment, management of mitigation and adaptation and urban planning are the major research purposes, while major research objects include GHG emissions, energy, water and health. China, Australia and India are the most investigated countries due to their high total GHG emissions and GHG emission intensities. Moreover, LCA, EF, GIS STIRPAT model, scenario analysis and urban metabolism are the mainstream research methods. In order to further improve the research in this field, it is critical to have more interdisciplinary study (such as hybrid methods) since no single method can deal with such a complicated issue. Especially, megacities deserve more attentions due to their complexity and higher GHG emissions. Research directions are proposed to guide researchers in this field to identify their future research fields. In addition, policy suggestions are raised to help decision makers prepare their own mitigation policies.

The main academic contribution of this paper is to provide a holistic picture of this emerging topic and identify future research direction and methods. The quantitative and qualitative analysis results can provide valuable insights and inspire scholars to further improve this field. It will also help policy makers initiate more appropriate policies on addressing climate change issues at the city level.

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References

Barboza, D., 2010. China passes Japan as second-largest economy. N. Y. Times 15.
Barles, S., 2009. Urban metabolism of Paris and its region. J. Ind. Ecol. 13 (6), 898–913.
Bastian, M., Heymann, S., Jacomy, M., 2009. Gephi: an open source software for exploring and manipulating networks. Icwsm 8, 361–362.
Bornmann, L., Daniel, H.D., 2007. What do we know about the h index? J. Assoc. Inf. Sci. Technol. 58 (9), 1381–1385.
Cohen, B., 2015. Urbanization, city growth, and the new united nations development agenda. Cornerstone 3, 4–7.
Cornish, E., 2004. Futuring: the Exploration of the Future. World Future Society.

Creutzig, F., He, D., 2009. Climate change mitigation and co-benefits of feasible transport demand policies in Beijing. Transport. Res. Transport Environ. 14 (2), 120–131.
Dong, H., Fujita, T., Geng, Y., Dong, L., Ohnishi, S., Sun, L., Dou, Y., Fujii, M., 2016. A review on eco-city evaluation methods and highlights for integration. Ecol. Indicat. 60, 1184–1191.
Duinker, P.N., Greig, L.A., 2007. Scenario analysis in environmental impact assessment: improving explorations of the future. Environ. Impact Assess. Rev. 27 (3), 206–219.
Ercan, T., Onat, N.C., Tatari, O., 2016. Investigating carbon footprint reduction potential of public transportation in United States: a system dynamics approach. J. Clean. Prod. 133, 1260–1276.
Everitt, B.S., Landau, S., Leese, M., Stahl, D., 2011. An Introduction to Classification and Clustering. Cluster Analysis, fifth ed., pp. 1–13
Fahimnia, B., Tang, C.S., Davarzani, H., Sarkis, J., 2015. Quantitative models for managing supply chain risks: a review. Eur. J. Oper. Res. 247 (1), 1–15.
Fan, Y., Liu, L.-C., Wu, G., Wei, Y.-M., 2006. Analyzing impact factors of CO_2 emissions using the STIRPAT model. Environ. Impact Assess. Rev. 26 (4), 377–395.
Feng, Y., Zhu, Q., Lai, K.-H., 2017. Corporate social responsibility for supply chain management: a literature review and bibliometric analysis. J. Clean. Prod. 158, 296–307.
Field, C.B., Barros, V.R., Dokken, D., Mach, K., Mastrandrea, M., Bilir, T., Chatterjee, M., Ebi, K., Estrada, Y., Genova, R., 2014. IPCC, 2014: Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.
Filimonau, V., 2016. The Life Cycle Thinking Approach and the Method of Life Cycle Assessment (LCA), Life Cycle Assessment (LCA) and Life Cycle Analysis in Tourism. Springer, pp. 9–42.
Forrester, J.W., 1961. Industrial Dynamics. MIT Press, Cambridge Mass.
Forrester, J.W., 1987. Lessons from system dynamics moodeling. Syst. Dynam. Rev. 3 (2), 136–149.
Geng, Y., Chen, W., Liu, Z., Chiu, A.S., Han, W., Liu, Z., Zhong, S., Qian, Y., You, W., Cui, X., 2017. A bibliometric review: energy consumption and greenhouse gas emissions in the residential sector. J. Clean. Prod. 159, 301–316.
Geng, Y., Sarkis, J., Wang, X., Zhao, H., Zhong, Y., 2013a. Regional application of ground source heat pump in China: a case of Shenyang. Renew. Sustain. Energy Rev. 18, 95–102.
Geng, Y., Zhao, H., Liu, Z., Xue, B., Fujita, T., Xi, F., 2013b. Exploring driving factors of energy-related CO_2 emissions in Chinese provinces: a case of Liaoning. Energy Policy 60, 820–826.
Geng, Y., 2011. Improve China's sustainability targets. Nature 477, 162.
Goodchild, M.F., 2009. Geographic Information System, Encyclopedia of Database Systems. Springer, pp. 1231–1236.
Heikkinen, R.K., Luoto, M., Araújo, M.B., Virkkala, R., Thuiller, W., Sykes, M.T., 2006. Methods and uncertainties in bioclimatic envelope modelling under climate change. Prog. Phys. Geogr. 30 (6), 751–777.
Hughes, S., Chu, E.K., Mason, S.G., 2017. Climate Change in Cities: Innovations in Multi-level Governance. Springer.
ISO, I., 2006. 14040: Environmental Management–life Cycle Assessment–principles and Framework. British Standards Institution, London.
Jin, W., Xu, L., Yang, Z., 2009. Modeling a policy making framework for urban sustainability: incorporating system dynamics into the ecological footprint. Ecol. Econ. 68 (12), 2938–2949.
Keleher, C.J., Rahel, F.J., 1996. Thermal limits to salmonid distributions in the Rocky Mountain region and potential habitat loss due to global warming: a geographic information system (GIS) approach. Trans. Am. Fish. Soc. 125 (1), 1–13.
Kennedy, C., Cuddihy, J., Engel-Yan, J., 2007. The changing metabolism of cities. J. Ind. Ecol. 11 (2), 43–59.
Lemos, M.C., Agrawal, A., 2006. Environmental governance. Annu. Rev. Environ. Resour. 31, 297–325.
Liddle, B., Lung, S., 2010. Age-structure, urbanization, and climate change in developed countries: revisiting STIRPAT for disaggregated population and consumption-related environmental impacts. Popul. Environ. 31 (5), 317–343.
Lin, S., Zhao, D., Marinova, D., 2008. Environmental impact of China: analysis based on the STIRPAT model. In: Second International Association for Energy Economics (IAEE) Asian Conference. Curtin University of Technology, pp. 164–192.
Liu, Z., Geng, Y., Dai, H., Wilson, J., Xie, Y., Wu, R., You, W., Yu, Z., 2018. Regional impacts of launching national carbon emissions trading market: a case study of Shanghai. Appl. Energy 230, 232–240.
Moore, S.A., 2007. In the nature of cities: urban political ecology and the politics of urban metabolism. Nik Heynen, Maria Kaika, and Erik Swyngedouw, eds. Urban Geogr. 28 (2), 206–208.
OECD, 2014. The Cost of Air Pollution.
OECD, 2017. Investing in Climate, Investing in Growth.
Ohnishi, S., Fujii, M., Ohata, M., Rokuta, I., Fujita, T., 2018. Efficient energy recovery through a combination of waste-to-energy systems for a low-carbon city. Resour. Conserv. Recycl. 128, 394–405.
Onat, N.C., Kucukvar, M., Tatari, O., Egilmez, G., 2016. Integration of system dynamics approach toward deepening and broadening the life cycle sustainability assessment framework: a case for electric vehicles. Int. J. Life Cycle Assess. 21 (7), 1009–1034.
Persson, O., Danell, R., Schneider, J.W., 2009. How to use Bibexcel for various types of bibliometric analysis. Celebrating scholarly communication studies: A Festschrift for Olle Persson at his 60th Birthday 5, 9–24.
Persson, O., Glänzel, W., Danell, R., 2004. Inflationary bibliometric values: the role of scientific collaboration and the need for relative indicators in evaluative studies. Scientometrics 60 (3), 421–432.
Pincetl, S., Bunje, P., Holmes, T., 2012. An expanded urban metabolism method: toward a systems approach for assessing urban energy processes and causes. Landsc. Urban Plann. 107 (3), 193–202.
Population Reference Bureau, 2018. Degree of Urbanization (Percentage of Urban Population in Total Population) by Continent in 2017. http://www.statista.com/statistics/270860/urbanization-by-continent/. (Accessed 3 June 2018).
Postma, T.J., Liebl, F., 2005. How to improve scenario analysis as a strategic management tool? Technol. Forecast. Soc. Change 72 (2), 161–173.
Ren, W., Xue, B., Geng, Y., Lu, C., Zhang, Y., Zhang, L., Fujita, T., Hao, H., 2016. Inter-city passenger transport in larger urban agglomeration area: emissions and health impacts. J. Clean. Prod. 114, 412–419.
Rosa, E.A., Dietz, T., 1998. Climate change and society: Speculation, construction and scientific investigation. Int. Sociol. 13 (4), 421–455.
Rosenzweig, C., Solecki, W.D., Romero-Lankao, P., Mehrotra, S., Dhakal, S., Ibrahim, S.A., 2018. Climate Change and Cities: Second Assessment Report of the Urban Climate Change Research Network. Cambridge University Press.
Runhaar, H., Driessen, P.P., Soer, L., 2009. Sustainable urban development and the challenge of policy integration: an assessment of planning tools for integrating spatial and environmental planning in The Netherlands. Environ. Plann. Plann. Des. 36 (3), 417–431.
Runhaar, H., Wilk, B., Persson, Å., Uittenbroek, C., Wamsler, C., 2018. Mainstreaming climate adaptation: taking stock about "what works" from empirical research worldwide. Reg. Environ. Change 18 (4), 1201–1210.
Sahin, O., Stewart, R.A., Porter, M.G., 2014. Water security through scarcity pricing and reverse osmosis: a system dynamics approach. J. Clean. Prod. 88 (3), 160–171.
Schoemaker, P.J., 1998. Twenty common pitfalls in scenario planning. Learning from the Future 422–431.
Scott, J., 2017. Social Network Analysis. Sage.
Sosa, B.S., Porta, A., Lerner, J.E.C., Noriega, R.B., Massolo, L., 2017. Human health risk due to variations in PM_{10}-$PM_{2.5}$ and associated PAHs levels. Atmos. Environ. 160, 27–35.
Suh, S., Lenzen, M., Treloar, G.J., Hondo, H., Horvath, A., Huppes, G., Jolliet, O., Klann, U., Krewitt, W., Moriguchi, Y., 2004. System boundary selection in life-cycle inventories using hybrid approaches. Environ. Sci. Technol. 38 (3), 657–664.
Tian, X., Geng, Y., Sarkis, J., Zhong, S., 2018a. Trends and features of embodied flows associated with international trade based on bibliometric analysis. Resour. Conserv. Recycl. 131, 148–157.
Tian, X., Geng, Y., Zhong, S., Wilson, J., Gao, C., Chen, W., Yu, Z., Hao, H., 2018b. A bibliometric analysis on trends and characters of carbon emissions from transport sector. Transport. Res. Transport Environ. 59, 1–10.
United Nations, 2015. The Paris Agreement under the United Nations Framework Convention on Climate Change (UNFCCC).
Wackernagel, M., Kitzes, J., Moran, D., Goldfinger, S., Thomas, M., 2006. The ecological footprint of cities and regions: comparing resource availability with resource demand. Environ. Urbanization 18 (1), 103–112.
Wasserman, S., Faust, K., 1994. Social Network Analysis: Methods and Applications. Cambridge university press.
Xi, F., Geng, Y., Chen, X., Zhang, Y., Wang, X., Xue, B., Dong, H., Liu, Z., Ren, W., Fujita, T., 2011. Contributing to local policy making on GHG emission reduction through inventorying and attribution: a case study of Shenyang, China. Energy Policy 39 (10), 5999–6010.
York, R., Rosa, E.A., Dietz, T., 2003. A rift in modernity? Assessing the anthropogenic sources of global climate change with the STIRPAT model. Int. J. Sociol. Soc. Pol. 23 (10), 31–51.
Yu, C., Dijkema, G.P., De Jong, M., Shi, H., 2015. From an eco-industrial park towards an eco-city: a case study in Suzhou, China. J. Clean. Prod. 102, 264–274.
Zhong, S., Geng, Y., Liu, W., Gao, C., Chen, W., 2016. A bibliometric review on natural resource accounting during 1995–2014. J. Clean. Prod. 139, 122–132.